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APPLICATION NUMBER: ***60/539,822***
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. *EV336596645US*

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Thomas W.	**Jenner Jr.**	**Seattle, Washington**

☐ *Additional inventors are being named on the ______ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

SYNTHETIC NERVOUS SYSTEM FOR ROBOTICS

CORRESPONDENCE ADDRESS

Direct all correspondence to:

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OR

☐ Firm or Individual Name					
Address					
Address					
City		State		ZIP	
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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 16 ☐ CD(s), Number ______

☒ Drawing(s) *Number of Sheets* 5 ☐ Other (specify) ______

☒ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

Filing Fee Amount: **$**

☐ A check or money order is enclosed to cover the filing fees.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

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Respectfully submitted,			
SIGNATURE	E. Russell Tarleton	DATE	**January 27, 2004**
TYPED or PRINTED NAME	**E. Russell Tarleton**	REGISTRATION NO. *(if appropriate)*	**31,800**
TELEPHONE	**206-622-4900**	DOCKET NUMBER:	**690113.402P1**

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

SYNTHETIC NERVOUS SYSTEM FOR ROBOTICS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is directed to robotic control systems and, more particularly, to analog circuitry that simulates natural neurons, including a central pattern generator utilizing the multiple domains of frequency, phase, amplitude, and DC offset.

Description of the Related Art

Robotic designs attempt to simulate the movement patterns of animals. With the exception of some lower invertebrates, animals have a nervous network that utilizes a central pattern generator to coordinate and synchronize the movements of their muscles. The central pattern generator has a pacemaker neuron functioning as a simple oscillator that does not require an input. The pacemaker neuron, when combined with a phase shifting network or interacting pacemaker neurons, causes the generation of an oscillating signal that is received at the muscle tissue through inter-neurons and motor neurons. In the time domain, these neurons communicate via voltage spikes. In other words, output voltage pulses are generated that can be measured in cycles per second.

This form of communication can be effective and robust, especially in the noisy environment where signal attenuation may occur over a long distance, *e.g.*, from the spinal cord to a human hand.

A substantial amount of research has taken place in this field with respect to robotics and artificial life. This research and its resulting applications tends to be not only complex but expensive. Very complex circuits using custom silicon and digital signal processors have been created to simulate how a natural central processing generator and nervous system work. Others have attempted to

create simple nervous network systems for robots. One example is found in U.S. Patent No. 5,325,031 issued to Tilden on June 28, 1994. Tilden teaches an adaptive robotic nervous system and control circuit for use with a limbed robot that utilizes a reconfigurable central network oscillator to sequence the processes of the robotic legs, each of which is itself autonomous. A pulse delay circuit is provided that, when connected to a second pulse delay circuit, acts as an artificial neuron. The device of Tilden suffers from several disadvantages, one of which is that the actuated limb has no way of detecting where it is in its phase space, and hence it limits feedback control beyond motor power consumption. In addition, Tilden utilizes Schmidt triggers in the central pattern oscillator that fire at one voltage and reset at a lower voltage to give a digital output, thus requiring more complicated circuitry and failing to take full advantage of the benefits of analog circuitry.

BRIEF SUMMARY OF THE INVENTION

The disclosed embodiments of the invention are directed to robotic systems, and particularly to control circuits for robotic systems, utilizing a basic motor neuron circuit that controls robotic movement. Analog circuits utilizing off-the-shelf servo motors, particularly those used in radio controlled aircraft and model cars, provide a simplified and cost-effective method for controlling locomotion and other robotic movement.

More specifically, in one embodiment of the invention analog electronic circuitry is produced that includes a plurality of basic motor neuron circuits controlled by a central pattern generator circuit to provide a continuously variable analog voltage. This voltage enables multiple motor neurons to coordinate their behavior to allow such robotic activities as walking, swimming, flapping, crawling, etc. By interfacing sensors to the synthetic nervous system, a wide range of adaptive behavior can be simulated by the robot, *e.g.* to following a light, avoiding an obstacle, shifting a balance point, and the like.

In accordance with another embodiment of the invention, a control circuit for an actuator is provided. The control circuit includes an analog central pattern generator circuit structured to generate a sine wave shaped control signal at an output and an analog multi-vibrator circuit having an input coupled to the output of the central pattern generator and an output configured to be coupled to the actuator. The analog multi-vibrator circuit is structured to generate a sine-variable rectangular wave signal in response to the control signal from the central pattern generator to drive the servo in a smooth sine movement pattern.

In accordance with another embodiment of the invention, a basic motor neuron circuit is provided. This circuit includes a first transistor having a control terminal coupled to an input, a first terminal coupled to a voltage source and a second terminal; a second transistor having a control terminal coupled to the second terminal of the first transistor, a first terminal coupled to the voltage source and to an output, and a second terminal coupled to a reference voltage; and a third transistor having a control terminal coupled to the output and to the voltage source, a first terminal coupled to the voltage source, and a second terminal coupled to the reference voltage.

In accordance with another aspect of the foregoing embodiment, this basic motor neuron circuit preferably includes a first capacitor coupled between the control terminal of the third transistor and the output, and a second capacitor coupled between the first terminal of the third transistor and the control terminal of the second transistor, the first and second capacitors configured to control timing for the circuit.

In accordance with another embodiment of the invention, the basic motor neuron circuit includes a first resistor and a second resistor coupled in series between the control terminal of the second transistor and the voltage source and configured to control a pulse width of a pulse signal generated on the output.

In accordance with yet another aspect of the invention, a robotic system is provided having at least one movable component coupled to a servo for

generating movement of the component, the robotic machine including: a control circuit coupled to the servo for controlling actuation of the servo, the control circuit including: a first transistor having a control terminal coupled to an input, a first terminal coupled to a voltage source and a second terminal; a second transistor having a control terminal coupled to the second terminal of the first transistor, a first terminal coupled to the voltage source and to an output, and a second terminal coupled to a reference voltage; and a third transistor having a control terminal coupled to the output and to the voltage source, a first terminal coupled to the voltage source, and a second terminal coupled to the reference voltage.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of the present invention will be more readily appreciated as the same become better understood from the following detailed description when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a circuit diagram of a basic motor neuron circuit formed in accordance with the present invention;

Figure 2 is a circuit diagram of a master-slave central pattern generator formed in accordance with the present invention;

Figure 3 is a frequency-modulated central pattern generator;

Figure 4 is a circuit diagram of a variable master-slave central pattern generator;

Figure 5 is a circuit diagram of an amplitude modulator circuit for use with a central pattern generator;

Figure 6 is an illustration of a DC offset modulator circuit for use with the basic motor neuron circuit and central pattern generator circuits; and

Figure 7 is a diagram of a control circuit for a four-legged eight-servo light-seeking robotic walker.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a circuit diagram of a basic motor neuron circuit 10 formed in accordance with one embodiment of the invention. This circuit is configured as a waveform generator for use with commercially available model-hobbyist type servos. The circuit 10 includes a rectangular wave multi-vibrator 12 formed of a first transistor (Q1) 14 and a second transistor (Q2) 16. A third transistor (Q3) 18 is configured to operate as a voltage-controlled resistor and is coupled between an input 20 and a control terminal or base of the third transistor 18. A first resistor 22 is coupled between the input 20 and the control terminal or base of the third transistor 18 and a second resistor 24 is coupled between the control terminal or base of the third transistor 18 and a voltage source 26, preferably set at 5 volts for this application. The second resistor 24 provides a bias to the third transistor 18 so that it operates in the linear region and, functionally, as a voltage-controlled resistor.

The third transistor 18 has a first terminal coupled to the voltage source 26 and a second terminal coupled to the voltage source 26 through a third resistor 28 and also to a control terminal of the first transistor 14 via a fourth resistor 30. The first transistor 14 has a first terminal coupled to the voltage source 26 via a fifth resistor 32 and also coupled via a sixth resistor 34 to an output 36. In addition, the first terminal of the first transistor 14 is also coupled to a control terminal of the second transistor 16 via a first capacitor 38. The control terminal of the second transistor 16 is also coupled to the voltage source 26 via a seventh resistor 40 and to ground through a second capacitor 43. The first terminal of the second transistor 16 is coupled to the voltage source 26 via an eighth resistor 42 and to the control terminal of the first transistor 14 via a third capacitor 44. The second terminals of the first and second transistors 14, 16 are coupled to a common reference potential 46, shown in this example with a ground symbol. A fourth capacitor 45 is coupled between the base of Q1 and ground.

As described above, the first and second transistors 14, 16 are coupled together to function as a square wave multi-vibrator 12. The fifth resistor 32 and the eighth resistor 42 are chosen to obtain a desired waveform at the output 36. The first and second capacitors 38, 44 are the timing capacitors for the circuit 10. The seventh resistor 40 controls the time between pulses at the output 36, and the value of this resistor is not critical so long as it provides pulses in the range of 20 milliseconds to 50 milliseconds. The third and fourth resistors, 28, 30 along with the third transistor 18 control the length of the pulse. Preferably, the third and fourth resistors 28, 30 are chosen to give about a 2-millisecond pulse, but the fourth resistor 30 can be variable to choose whatever is appropriate for the circuit.

The Vin input 20 functions as a signal summation point for the output of other circuits to be described below. Zero volts at the Vin input 20 provides roughly a 2-millisecond pulse at the output 36, and 5 volts at the input 20 provides approximately 1-millisecond pulses. These pulses are preferably provided directly to a commercially available servo (not shown) that is coupled to the output 36.

Bipolar or integrated NPN transistors may be used in this circuit 10. While operational amplifiers can be used, cost and simplification is a goal and hence operational amplifiers are not preferred for this circuit.

Turning next to Figure 2, shown therein is a master-slave central pattern generator circuit 48 formed in accordance with the present invention to include a first section 50 and a second section 52. The first section includes a fourth transistor (Q4) 54 having a control terminal coupled to a voltage source 56, which could be the same voltage source 26 used with the basic motor neuron circuit 10 when these circuits are coupled together. A ninth resistor 58 is interposed between the voltage source 56 and the control terminal of the fourth transistor 54. The fourth transistor 54 has a first terminal coupled to the voltage source 56 via a tenth resistor 60 and also coupled to an output 62 via an eleventh

resistor 64. The first terminal of the fourth transistor 54 is also coupled to the control terminal of a fifth transistor (Q5) 66 via a twelfth resistor 68.

The fourth transistor 54 also has its first terminal coupled to its control terminal via a third capacitor 70, fourth capacitor 72, and fifth capacitor 74 series coupled together. A second terminal of the fourth transistor is coupled to a ground reference potential 76 and to a sixteenth resistor 78 that is coupled between the third and fourth capacitors 70, 72 and to a seventeenth resistor 80 coupled between the fourth capacitor 72 and the fifth capacitor 74.

Turning to the second section 52, this section includes the fifth transistor 66 in which the control terminal is coupled to the voltage source 56 via a thirteenth resistor 82, a first terminal is coupled to the voltage source 56 via a fourteenth resistor 84, and to an output 86 via a fifteenth resistor 88. In addition, the fifth transistor 66 has its first terminal coupled to its control by series connected sixth, seventh, and eighth capacitors 90, 92, 94. The second terminal of the fifth transistor 66 is coupled to the ground reference potential 76, and to an eighteenth resistor 96 coupled between the sixth and seventh capacitors 90, 92 and to a nineteenth resistor 98 coupled between the seventh and eighth capacitors 92, 94.

The first and second sections 50, 52 are single transistor sine wave oscillators. The sixteenth through the nineteenth resistors 78, 80, 96, 98 and the third through the eighth capacitors 70, 72, 74, 90, 92, 94 cooperate to provide the RC timing constants. The RC time constant should be in the range of 0.5 to 3.0 seconds. The value of the ninth, tenth, thirteenth and fourteenth resistors 58, 60, 82, 84 are chosen for best waveform output. Each of the first and second oscillators 50, 52 has its own basic motor neuron output 62, 86 through the eleventh resistor 64 and the fifteenth resistor 88. However, the first section 50 has its output coupled to the input 20 of the basic motor neuron circuit 10 shown in Figure 1. The second section 52 is a slave that is out of phase with the first section 50. The central pattern generator 48 does not have an input and

commences generating a single sine wave at the output 62 of the first section 50 upon power-up.

The first and section sections 50, 52 are lightly coupled together through the twelfth resistor 68. In this manner, the second section 52 becomes phase locked and phase shifted with respect to the first section 50. The first, second, and fourth periods and chaotic phase orbits of these circuits can be measured at the twelfth resistor 68 and a fifteenth resistor 88 with proper adjustment of the tenth resistor 60 and the fourteenth resistor 84, which are used to modify the sine wave output.

By tapping the output 62 of the first section 50 to the input 20 of the basic motor neuron circuit 10, a sine variable rectangular waveform will appear at the output 36 of the basic motor neuron 10, which is used as an input to a servo or actuator. This will cause the servo shaft to turn back and forth in a smooth sine pattern. This back-and-forth motion forms the basic action of robotic locomotion in a synthetic nervous system consisting of the basic motor neuron circuit 10 and a central pattern generator circuit 48.

Adding an additional RC pole to the central pattern generator sine wave signal will provide greater oscillator stability and modify the sine wave so that it may be more appropriate to certain locomotion schemes.

Turning next to Figure 3, shown therein is a frequency modulated central pattern generator circuit 100 formed in accordance with another embodiment of the present invention. This circuit 100 includes a sixth transistor 102 having its control terminal coupled to a voltage source 104 via a twentieth resistor 106, and having its first terminal also coupled to the voltage source 104 via a twenty-first resistor 108. The first terminal is also coupled to an output 110 via a twenty-second resistor 112 and to its control terminal by series coupled ninth, tenth, and eleventh capacitors 114, 116, 118. The sixth transistor also has a second terminal that is coupled to a ground reference potential 120 and to a twenty-third resistor 122 that has its other terminal coupled between the ninth and

tenth capacitors 114, 116. A tenth transistor 124 has its control coupled to a 5-volt voltage source, such as the voltage source 104 referenced above, via a twenty-fifth resistor 126 and also coupled to a frequency input terminal 128 via a twenty-fourth resistor 130. This tenth transistor 124 has a first terminal coupled between the tenth and eleventh capacitors 116, 118 and a second terminal coupled to the ground reference potential 120 via a twenty-sixth resistor 132.

This frequency-modulated central pattern generator circuit 100 is configured to replace one of the RC timing resistors, such as the nineteenth resistor 98 in the master-slave central pattern generator 48 or the seventeenth resistor 80 in the first section 50 thereof. For example, if the nineteenth resistor 98 were replaced with the frequency-modulated central pattern generator circuit 100, the output 110 thereof would be coupled between the seventh and eighth capacitors 92, 94. The twenty-fourth through the twenty-sixth resistors 130, 126, 132, respectively, and the sixth transistor 102 cooperate act as a high-impedance voltage controlled resistor. This enables modification of the central pattern generator 48 so that it can be sped up or slowed down, and it also allows for more complex waveforms. Thus, this circuit 100 provides for frequency modification of the central pattern generator 48 of Figure 2 and hence of the basic motor neuron circuit 10.

Turning next to Figure 4, shown therein is a variable master-slave central pattern generator circuit 48 modified to enable phase shifting of the output signal, which allows reversing of the circuit and hence the motion of the servo connected at the output 36 of the basic motor neuron circuit 10. In Figure 4, elements is common with those shown in Figure 2 have the same reference number. Here, eleventh, twelfth, and thirteenth transistors 134, 136, 138 are added to form the variable master-slave central pattern generator circuit 140. The twelfth transistor 136 has a control terminal coupled to a phase shift input 144 via a twenty-seventh resistor 142, and a first terminal coupled to the twelfth resistor 68. A second terminal of the twelfth transistor 136 is coupled directly to the control of

the fifth transistor 66. The eleventh transistor 134 has a control terminal coupled to the phase shift input 144 via a twenty-eighth resistor 146, a first terminal coupled to a 5-volt voltage source 56, and a second terminal coupled to the control of the thirteenth transistor 138 by a twenty-ninth resistor 148 and to the ground reference potential 76 via a thirtieth resistor 150. Finally, the thirteenth transistor 138 has its first terminal coupled to the first terminal of the fifth transistor 66 via a thirty-first transistor 152 and its second terminal coupled directly to the control of the fourth transistor 54.

In this modified variable central pattern generator 140, the eleventh transistor 134 receives a 0-volt to 5-volt phase shift input signal at the phase shift input 144 to invert the phase shift signal so that only the twelfth or thirteenth transistor 136, 138, respectively, is on at any one time. These two transistors are structured to control the flow of information, and this simple arrangement allows the twelfth transistor 136 to be phase shifted from about 90 degrees to 270 degrees in relation to the thirteenth transistor 138, enabling simple reversing of the robotic direction.

Amplitude modulation of the sine wave output signal generated by the central pattern generator 48 is provided via the amplitude modulator circuit 154 shown in Figure 5. Here, a seventh transistor (Q7) 156 has its control terminal coupled to an amplitude input 158 via a thirty-first resistor 160 and to a voltage source, such as voltage source 56, via a thirty-second resistor 162. The first terminal of the seventh transistor 156 is coupled to the output 62 of the first section 50, and the second terminal of this transistor forms the output of the amplitude modulator circuit 154, which is received at a DC offset modulator circuit 164 in Figure 6. An amplitude input control signal is received at the amplitude input 158.

Turning to Figure 6, the DC offset modulator circuit 164 consists of series-coupled eighth and ninth transistors 166, 168 in which the control terminal of the eighth transistor 166 is coupled to a first offset input 170 via a thirty-third resistor 172, a second terminal is coupled to a DC input 174 via a thirty-fourth

resistor 176. The ninth transistor 168 has a control terminal coupled to a second DC offset input 178 via a thirty-fifth resistor 180.

The eighth transistor 166 also has a first terminal coupled to a voltage source 56 via a thirty-sixth resistor 182, and its second terminal is also coupled to a DC output 184 via a thirty-seventh resistor 186. The ninth transistor 168 has its first terminal coupled to the second terminal of the eighth transistor 166 and hence to the thirty-seventh resistor 186. A second terminal of the ninth transistor 168 is coupled to the ground reference potential 76 via a thirty-eighth resistor 188.

The DC offset modulator circuit 164 is configured so that the DC input 174 is coupled to the second terminal of the seventh transistor 156 in the amplitude modulator circuit 154. The DC output 184 is then coupled to the Vin input 20 of the basic motor neuron circuit 10 of Figure 1. The DC offset modulator circuit 164 is utilized for balancing and steering of the robotic machine in combination with the amplitude modulator circuit 154 of Figure 5. The amplitude modulator circuit 154 provides for amplitude adjustment of the sine wave output from the sine wave oscillator of the first section 50.

The DC output 184 from the DC offset modulator 164 and the output 110 from the frequency-modulated central pattern generator circuit 100 are configured to be summed at the Vin input 20 of the basic motor neuron circuit 10 to provide full control of the servos the resulting movement of the robotic machine.

Figure 7 is a control circuit for a four-legged eight-servo light-seeking robotic walker machine. The control circuit 190 utilizes sixteen oscillators and thirty-four transistors, preferably NPN transistors, arranged as a synthetic nervous system. Pairs of sine oscillators are configured as central pattern generators 48, as shown in Figure 2 to control each leg of the robotic machine. More particularly, a first leg control circuit 192 includes oscillators Sine 1 and Sine 2, which are the first and second sections 50, 52 of the central pattern generator 48 of Figure 2. Coupled to Sine 1 is the amplitude modulator circuit 154 that in turn is coupled to

the basic motor neuron circuit 10 of Figure 1, as is Sine 2, which is coupled to the output 86 from the second section 52 for the basic motor neuron circuit 10.

Similar construction is used for the second leg control circuit 194. The third and fourth leg control circuits 196, 198 only utilize the central pattern generator 48 and the basic motor neuron circuit 10.

Sine oscillators 1, 3, 5, and 7 are configured to control forwards and backwards leg swing while Sine oscillators 2, 4, 6, and 8 are configured to control the up and down movements of the leg. Amps 1 and 2 are the amplitude modulator circuits 154 of Figure 5 that are controlled through a cross-connected light-dependent sensor circuit 200. The sensor circuit 200 consists of a first light dependent resistor 202 and second light dependent resistor 204 powered by the voltage source 26, preferably at 5 volts, and connected to ground reference potential 46 via first and second resistive elements 206, 208. A first output node 210 is formed at the connection between the first resistive element 206 and the first light dependent resistor 202, and a second output node 212 is formed at the connection between the second resistive element 208 and the second light dependent resistor 204. The first output node 210 is coupled to the amplitude input 158 of Amp 2, and the second output node 212 is coupled to the amplitude input 158 of Amp 1. This controls the amount of swing in the front legs in proportion to the amount of light received at the light dependent resistors 202, 204. Cross-tying the light dependent resistors 202, 204 enables light-seeking behavior by the robotic machine.

The collector of Sine 1 is wired to the base of Sine 7, as is the collector of Sine 1 wired to the base of Sine 2. Sine 1 and 7 are locked about 90 degrees out of phase. Sine 7 is connected to Sine 5 and 8 in the same collector-to-base fashion. Sine 5 is connected to Sine 3 and 6, and Sine 3 is connected to Sine 4. Ideally, these connections are made through a resistor, preferably of a value similar to the value of resistor 68 (R9) of Figure 2.

All of the leg pairs 192, 194, 196, 198 are phase locked roughly 90 degrees from each other. On an oscilloscope in the "XY" setting, this will show a roughly circular phase orbit. When connected to the basic motor neuron circuit 10 and wired to a servo, this will cause the legs to show forward locomotion.

Because Sine oscillators 1, 7, 5, and 3 are roughly 90 degrees out of phase, this will cause each leg in the robotic machine to swing forward in proper phase unison. Because Sine oscillators 2, 4, 6, and 8 are driven by the second section 52, which is phase shifted from the first section 50, this will coordinate lifting of the legs at the time the legs are moving forward, thus enabling a forward walking motion. Amps 1 and 2 control the amount of leg swing through signals received from the light sensor circuit 200 to enable the robotic machine or quadpod to walk towards a light source.

Although a preferred embodiment of the invention has been illustrated and described, it is to be understood that various changes may be made therein without departing from the spirit and scope of the invention. For example, a master oscillator having an op amp phase shifter may be more appropriate in some situations. In addition, although bipolar transistors have been illustrated and NPN and other integrated transistors have been described, it is to be understood that bipolar or integrated transistors may be used exclusively or in any combination thereof. Hence, the invention is to be limited only by the scope of the claims that follow and the equivalents thereof.

All of the above U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet, are incorporated herein by reference, in their entirety.

CLAIMS

1. A control circuit for an actuator, comprising:

an analog central pattern generator circuit structured to generate a sine wave control signal at an output; and

an analog multi-vibrator circuit having an input coupled to the output of the central pattern generator and an output configured to be coupled to the actuator, the multi-vibrator circuit structured to generate a sine-variable rectangular wave signal in response to the control signal from the central pattern generator to drive the servo in a sine movement pattern.

2. A basic motor neuron circuit, comprising:

a first transistor having a control terminal coupled to an input, a first terminal coupled to a voltage source and a second terminal;

a second transistor having a control terminal coupled to the second terminal of the first transistor, a first terminal coupled to the voltage source and to an output, and a second terminal coupled to a reference voltage; and

a third transistor having a control terminal coupled to the output and to the voltage source, a first terminal coupled to the voltage source, and a second terminal coupled to the reference voltage.

3. The circuit of claim 2, further comprising a first capacitor coupled between the control terminal of the third transistor and the output, and a second capacitor coupled between the first terminal of the third transistor and the control terminal of the second transistor, the first and second capacitors configured to control timing for the circuit.

4. The circuit of claim 2, further comprising a first transistor and a second transistor coupled in series between the control terminal of the second transistor

and the voltage source and configured to control a pulse width of a pulse signal generated on the output.

5. A robotic machine having at least one movable component coupled to a servo for generating movement of the component, the robotic machine comprising:

a control circuit coupled to the servo for controlling actuation of the servo, the control circuit comprising:

a first transistor having a control terminal coupled to an input, a first terminal coupled to a voltage source and a second terminal;

a second transistor having a control terminal coupled to the second terminal of the first transistor, a first terminal coupled to the voltage source and to an output, and a second terminal coupled to a reference voltage; and

a third transistor having a control terminal coupled to the output and to the voltage source, a first terminal coupled to the voltage source, and a second terminal coupled to the reference voltage.

ABSTRACT OF THE DISCLOSURE

A synthetic nervous system for robotic applications having a control circuit and servo actuators using continuously variable analog voltages to mimic natural bio-neural processes. A central pattern generator utilizing quasi-periodic or chaotic oscillators or phase shifters, or a combination thereof, along with a basic motor neuron circuit enables multiple motor neurons to coordinate their behavior to enable such things as walking, swimming, flapping, crawling, and the like. Sensors interfaced to the control circuit provide a wide range of adaptive behavior such as following light, avoiding an obstacle, and shifting balance point. Overlapping or concurrent behavior can provide complex behaviors with minimal circuitry.

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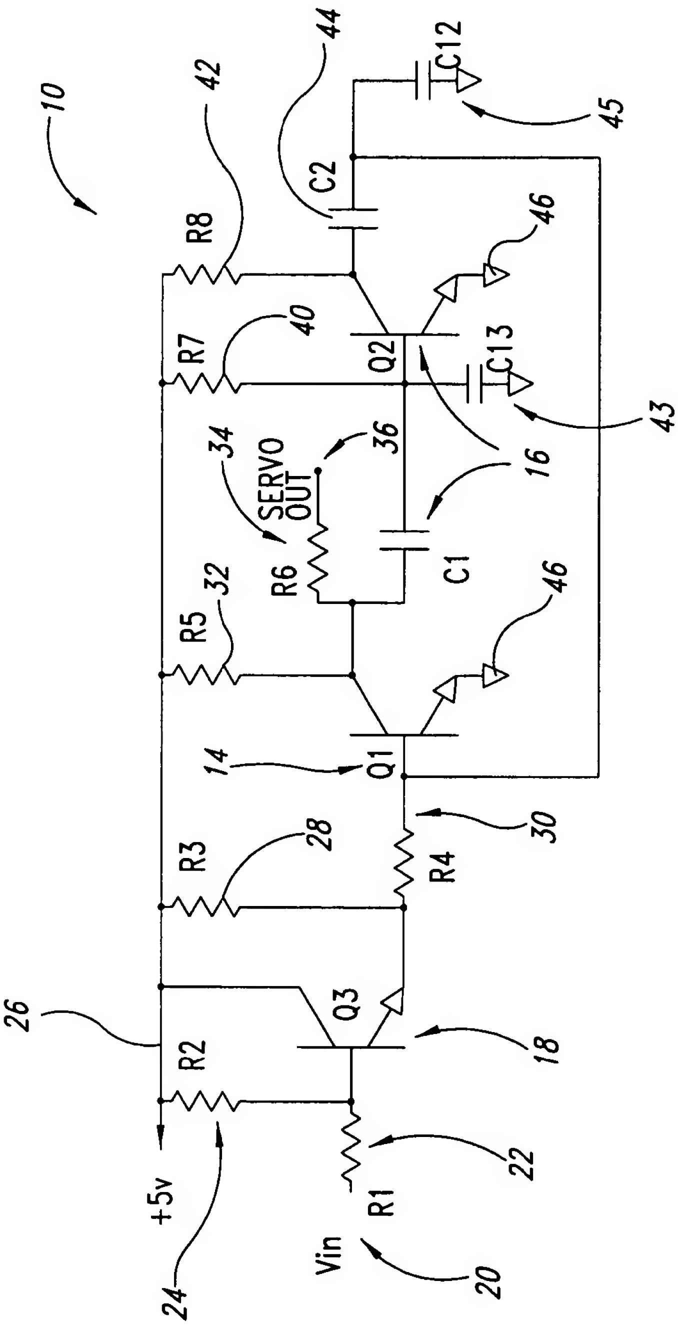
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FIG. 1

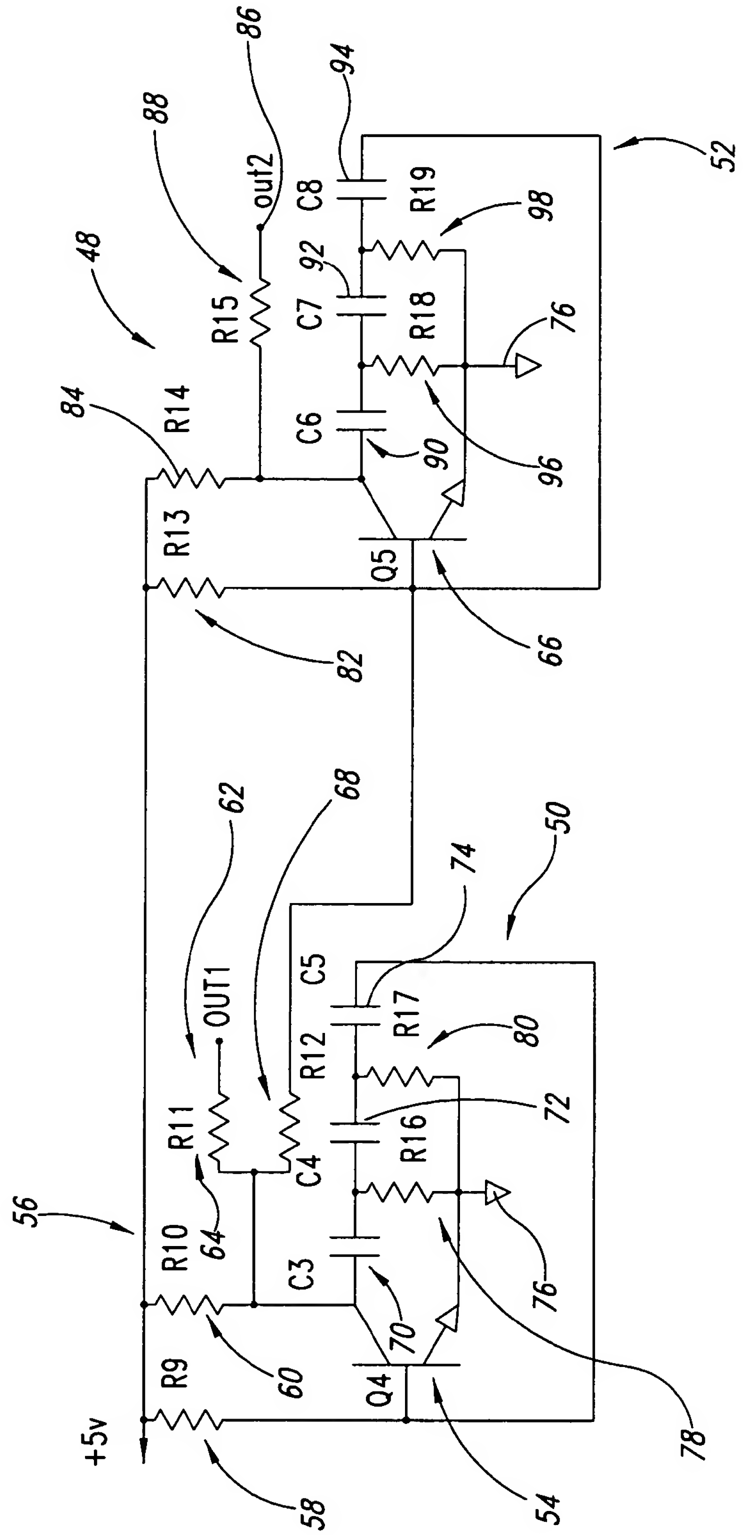
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FIG. 2

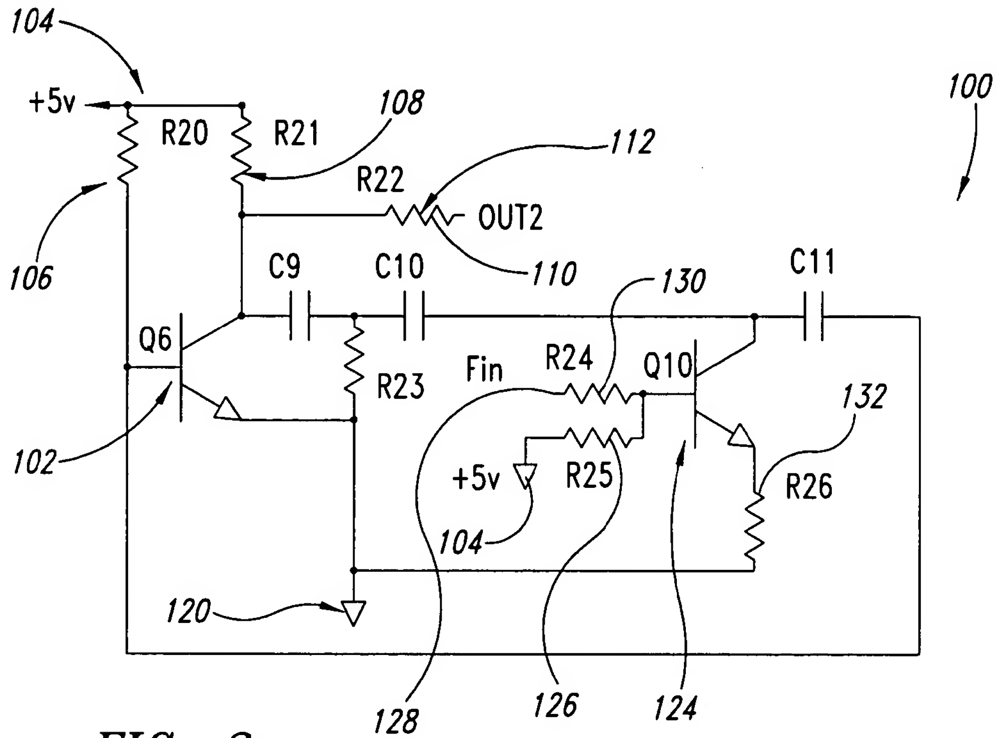


FIG. 3

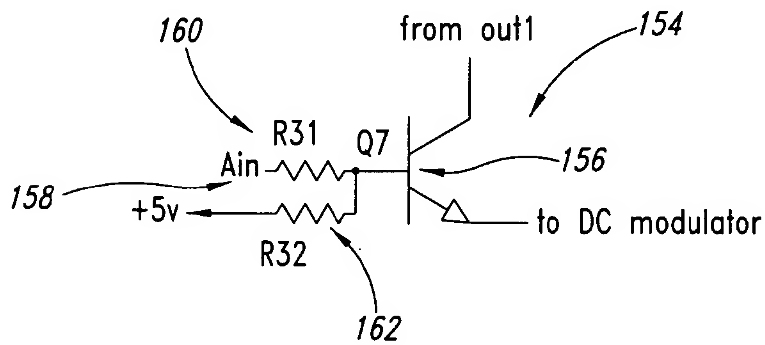


FIG. 5

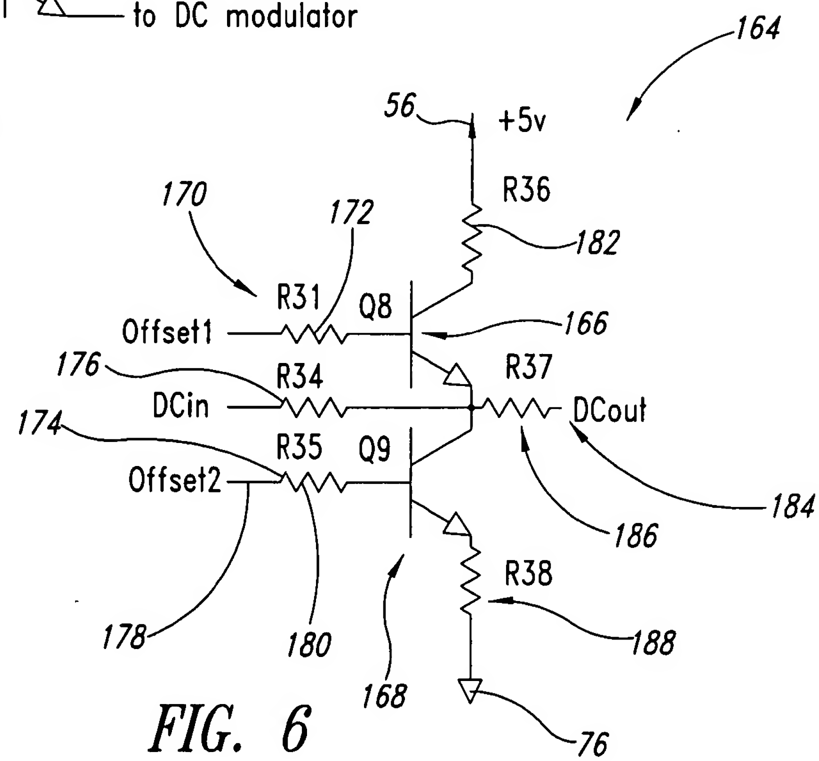
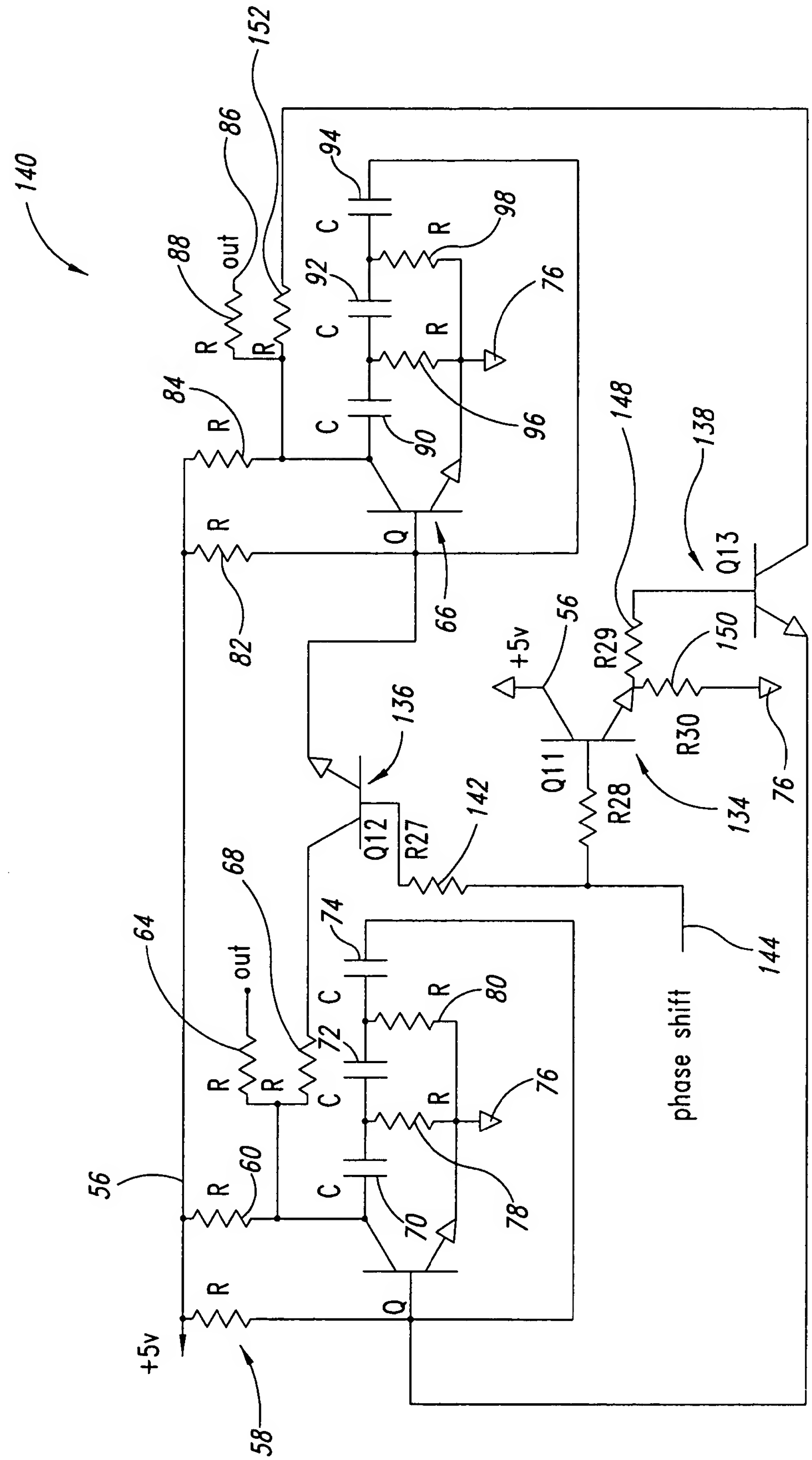


FIG. 6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134
136
Q12
R27
142
144
phase shift
64
68
out
R
R
72
C
C
C
74
R
R
80
76
78
70
56
60
R
R
Q
+5v
58

FIG. 4

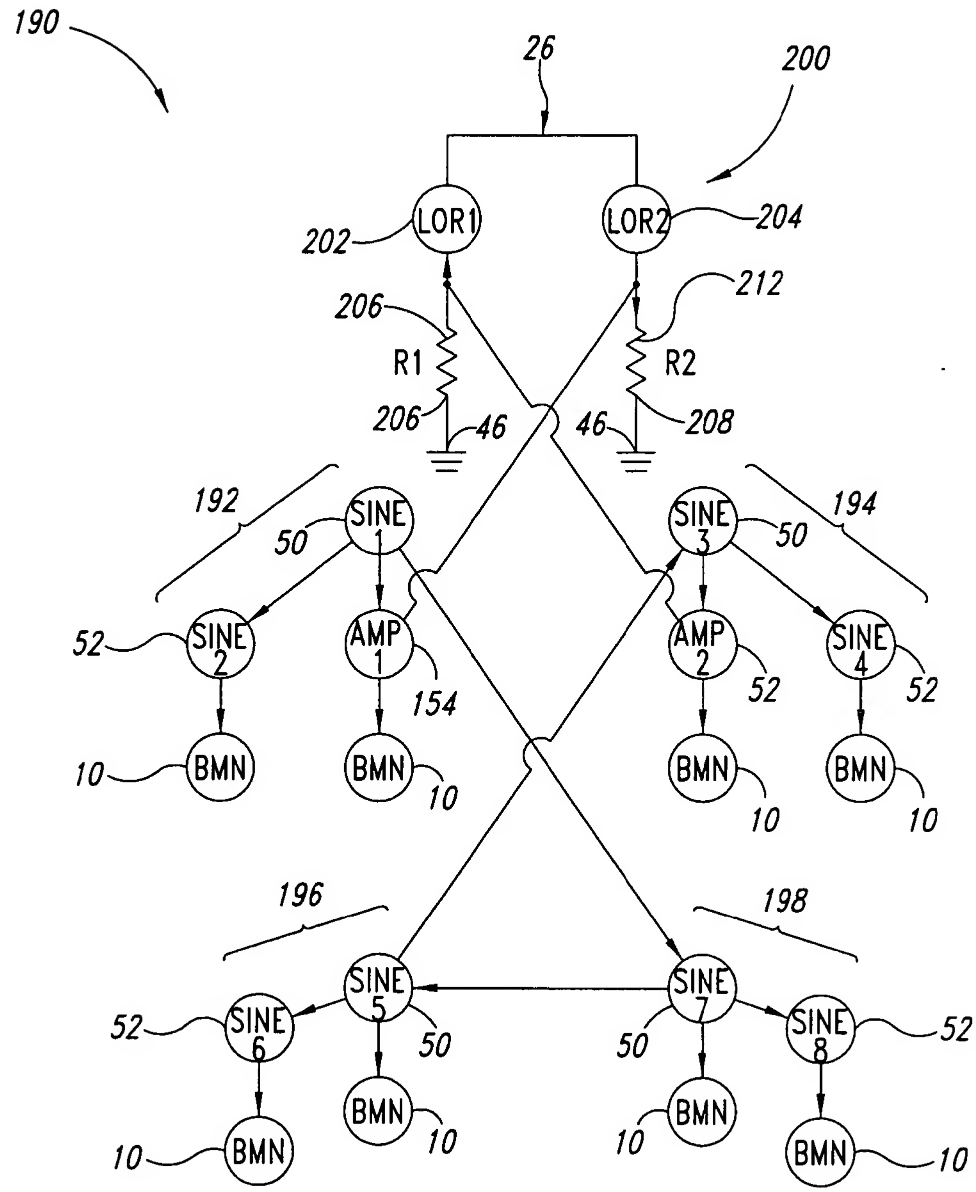
190
26
200
LOR1
LOR2
202
204
206
212
R1
R2
206
46
46
208
192
194
SINE 1
SINE 3
50
50
SINE 2
AMP 1
AMP 2
SINE 4
52
154
52
52
BMN
BMN
BMN
BMN
10
10
10
10
196
198
SINE 5
SINE 7
SINE 6
SINE 8
52
50
50
52
BMN
BMN
BMN
BMN
10
10
10
10

FIG. 7

APPLICATION DATA SHEET

Application Information

Application number::	
Filing Date::	
Application Type::	Provisional
Subject Matter::	Utility
Suggested classification::	
Suggested Group Art Unit::	
CD-ROM or CD-R?::	None
Number of CD disks::	
Number of copies of CDs::	
Sequence submission?::	
Computer Readable Form (CRF)?::	No
Number of copies of CRF::	
Title ::	SYNTHETIC NERVOUS SYSTEM FOR ROBOTICS
Attorney Docket Number::	690113.402P1
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	
Total Drawing Sheets::	5
Small Entity?::	Yes
Petition included?::	No
Petition Type::	
Licensed U.S. Gov't Agency::	
Contract or Grant No::	
Secrecy Order in Parent Appl.?::	No

First Applicant Information

Applicant Authority Type::	Inventor
Primary Citizenship Country::	US
Status::	Full Capacity
Given Name::	Thomas
Middle Name::	W.
Family Name::	Jenner
Name Suffix::	Jr.
City of Residence::	Seattle
State or Province of Residence::	WA
Country of Residence::	US
Street of mailing address::	300 Queen Anne Avenue North #279
City of mailing address::	Seattle
State or Province of mailing address::	WA
Country of mailing address::	US
Postal or Zip Code of mailing address::	98109

Correspondence Information

Correspondence Customer Number :: **00500**

Representative Information

Representative Customer Number::		**00500**

Domestic Priority Information

Application ::	Continuity Type::	Parent Application::	Parent Filing Date::

Application ::	Continuity Type::	Parent Application::	Parent Filing Date::

Foreign Priority Information

Country::	Application number::	Filing Date::	Priority Claimed::

Assignee Information

Assignee name::	New School Technologies, LLC
Street of mailing address::	7683 Southeast 27th Street
City of mailing address::	Mercer Island
State or Province of mailing address::	WA
Country of mailing address::	US
Postal or Zip Code of mailing address::	98040

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